

**Draft Plan for NPAFC Bering-Aleutian Salmon
International Survey (BASIS)
2002-2006**

**Committee on Scientific Research and Statistics
Science Sub-Committee**

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

**Committee on Scientific Research and Statistics
Science Sub-Committee**

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Project Summary

Draft Plan for NPAFC Bering-Aleutian Salmon International Survey (BASIS)

Problem/Issue

Unanticipated changes in the ocean productivity of Bering Sea ecosystem are affecting Asian and North American societies and economies through reduction and possible elimination of important commercial and subsistence fisheries. Experts agree that the future of the Bering Sea fishery resources are uncertain: the lack of long-term, large-scale observation systems for salmon in the Bering Sea has inhibited scientific understanding of these changes. An international effort is required to detect and monitor changes in salmon and their ecosystem because stocks from all major salmon producing nations are distributed in the Bering Sea, intermingle in international waters, and migrate across the national economic zones. At the 2001 annual meeting of the North Pacific Anadromous Fish Commission (NPAFC), Canada, Japan, Russia, and the United States agreed to plan and coordinate a new international program that will form the basis for long-term, large-scale ecosystem research on salmon in the Bering Sea.

Survey Plan Elements

The scientific concepts behind the NPAFC Bering-Aleutian Salmon International Survey (BASIS) are simple; yet the results will revolutionize our understanding of salmon and the Bering Sea ecosystem. The plan calls for four synoptic 1-month seasonal (spring, summer, fall, winter) surveys per year for 5 years. The survey area consists of 105 sampling stations spaced at regular intervals across the Bering Sea: from the Aleutians north to 64°N, and from the Alaskan to Russian coasts. Sampling would consist of surface trawls to capture salmon and other fish, plankton tows, and sampling of ocean conditions (e.g., salinity, temperature, currents). Coordination of sampling by vessels of four nations would be through the NPAFC.

In-depth biological and stock identification analyses will determine growth and life history characteristics of regional stock groups. The stock identification analyses would be based on genetic, parasite, scale, otolith, and tag data. BASIS data will be used in spatially-explicit models incorporating oceanographic data and salmon migration, growth, and mortality processes to advance our understanding of the causes of changes in productivity of salmon populations.

Survey Plan Benefits

BASIS provides the first ever synoptic seasonal information on distribution, abundance, and stock origins of all species, age, and maturity groups of salmon in the Bering Sea.

BASIS directly addresses the key elements of the 2001-2005 NPAFC Science Plan.

BASIS complements long-term climate, ocean, and ecosystem research and monitoring activities by other international organizations such as the North Pacific Marine Science Organization (PICES) and Global Ocean Ecosystem Dynamics (GLOBEC).

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Project Description

NPAFC Bering-Aleutian Salmon International Survey (BASIS)

1. Cooperating International Organizations, Government Agencies, and Universities

This list includes organizations, government agencies, and universities that participated in the initial development and review of this proposal.

International Organizations

North Pacific Anadromous Fish Commission (Vancouver, B.C.)

Government Agencies and Universities

Canada: Dept. of Fisheries and Oceans, Pacific Biological Station (Nanaimo, B.C.)

Japan: Fisheries Agency of Japan (Tokyo); Fisheries Research Agency, Hokkaido National Fisheries Research Institute (Kushiro); National Salmon Resources Center (Sapporo); Hokkaido University (Sapporo and Hakodate)

Russia: Russian Federal Research Institute of Fisheries & Oceanography (Moscow); Kamchatka Research Institute of Fisheries & Oceanography (KamchatNIRO, Petropavlovsk-Kamchatsky); Pacific Scientific Research Fisheries Centre (TINRO-Centre, Vladivostok); Pacific Scientific-Research Center Fishing Industry TINRO-Center Khabarovsk Branch; TINRO, Magadan Branch; Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO, Yuzhno-Sakhalinsk)

U.S.A.: National Marine Fisheries Service, Alaska Fisheries Science Center (Seattle), Auke Bay Laboratory (Juneau); Alaska Department of Fish and Game (Juneau, Anchorage); University of Alaska Fairbanks (Juneau); University of Washington (Seattle)

2. Introduction

The North Pacific Anadromous Fish Commission (NPAFC) was established in 1992 by the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean, which is the international treaty that banned high seas fishing for salmon in the North Pacific Ocean. Four nations are party to the treaty: U.S., Canada, Japan, and Russia. The primary purpose of the NPAFC is the conservation of anadromous species--most notably salmon-- and "ecologically-related species." This is carried out through two major functions: scientific research and enforcement of the high seas fishing ban.

Cooperation on scientific research reached a new level of coordination and collaboration at the 2000 NPAFC Annual Meeting. For the first time, the four nations agreed to go beyond coordinating their individual research plans by developing a joint set of research priorities. This is an unprecedented opportunity for all nations to gain regional cooperation on high seas salmon conservation and management issues. The decline in ocean growth and survival of Bering Sea

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salmon populations and the resulting economic disasters in western Alaska are major priorities for U.S. interests.

In March 2001 the NPAFC Research Planning and Coordinating Group agreed to develop a specific project-oriented plan, the Bering-Aleutian Salmon International Survey (BASIS), that would provide the basis for international cooperative research on Bering Sea salmon in NPAFC. The proposed survey would establish when and where salmon stocks migrate and rear in the Bering Sea, and will clarify the mechanisms of biological response by salmon to the conditions affected by climate changes. The NPAFC can play a vital role in providing continued focus on these issues by coordinating research in coastal and offshore waters, and by providing a forum for the dissemination of new scientific knowledge.

Although worldwide catches of Pacific salmon have reached record levels in recent years, salmon runs to rivers emptying into the Bering Sea have been inconsistent and at times very weak. Low returns of chinook and chum salmon to the Yukon River, Kuskokwim River, and Norton Sound area (hereafter called AYK region) of Alaska prompted the State of Alaska in 2000 to restrict commercial and subsistence fisheries and declare the region a disaster area. For example, the commercial catch of chinook salmon in the Yukon River was less than 10 percent of the long-term average and the lowest since 1937. The weak AYK salmon runs follow several years of low sockeye runs to Bristol Bay, which was declared a disaster region in 1998 by both the State of Alaska and the U.S. Department of Commerce.

On the Asian side, catches of chum salmon in East Kamchatka in the 1990s decreased to about one third of the catches in the late 1970s and in the 1980s. Catches of E. Kamchatka chinook salmon have declined precipitously since 1977 and coho salmon are in decline as well. Recently, Russian commercial catches of sockeye, pink, and chum have improved in response to greater restrictions on ocean salmon fisheries. Since 1997, returns of Japanese chum salmon have decreased, but harvests are still at an historically high level. We have observed declines in the size of adults returning to Bering Sea river systems and reductions in growth rates of Asian salmon rearing in Bering Sea waters. Reduced growth and increasing age-at-return of Japanese chum salmon may be related to density-dependent intraspecific and interspecific competition of salmon that migrate into the Bering Sea each summer to feed.

The reduced growth and production of Bering Sea salmon are mirrored by long-term changes in food availability. Macrozooplankton biomass has steadily decreased since the mid-1960s, reaching historic lows in the mid-1990s. Bering Sea carrying capacity, measured by carbon isotope ratios in whale baleen plates, has also shown a constant decrease since 1966, dropping abruptly in 1994, the same year in which age 0.3 chum salmon returning in 1997 would have entered the marine environment.

These concurrent changes in carrying capacity and salmon growth and production are not coincidental, but show a clear linkage between the marine environment and salmon production. Specific mechanisms underlying these linkages, however, are unknown principally due to the absence of information on salmon during their early marine period and to sparse and likely outdated data on the life history of immature and maturing salmon as they travel the waters of the Bering Sea. For some of the stocks, such as Kuskokwim or Yukon chum salmon, we have virtually no information about their first year at sea: where they migrate after leaving the rivers or if they overwinter in Bering Sea waters. We do know that many stocks of salmon move into

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the Bering Sea later in their development in preparation for the long journey back to natal streams, but we again have no data on the specifics of their residence. Because of the lack of basic life-history data, we are unable to test hypotheses about the causes of recent changes in salmon production and growth.

Salmon experts have long recognized the need to know the productivity of each component of the population mixtures studied (Thompson 1962); and that “real progress” in our ability to accurately observe and measure changes in productivity depends on “the measurement of biological and environmental parameters at the time and place where the fish occur during their ocean life” (Rogers 1988).

This research plan is intended to provide a scientific foundation by which we can determine the causes of changes in productivity of Bering Sea salmon populations. Our primary methodological approach is to conduct an international survey of salmon and their ecosystem in the Bering Sea, deploying survey vessels at key times and areas to provide, among other things, a seasonal picture of the migration and ecology of salmon inhabiting the Bering Sea, particularly those stocks exhibiting recent declines in production. A 5-year program of field, laboratory, and computer modeling research would enable us to track at least one cohort of the longer-lived salmon species (sockeye, chum, and chinook salmon) through a complete Bering Sea production cycle. Through this research plan, we hope that a clear understanding of salmon carrying capacity in the Bering Sea will result: from their first entry into the marine environment, to their departure from coastal to offshore waters where they develop and migrate extensively, and then their return back to home streams.

3. BASIS Objectives

The goal of BASIS is to understand the mechanisms underlying the effects of environmental variation and density-dependence on salmon carrying capacity in the Bering Sea for sustainable conservation of salmon stocks (Fig. 1). “Carrying capacity” is the biomass of a species that can be maintained by the ecosystem resources and conditions (Radchenko 2001). Key scientific questions incorporated into the 2001-2005 NPAFC Science Plan provide necessary direction to the research: 1) What are the seasonal-specific migration patterns of salmon and their relation to the Bering Sea ecosystem?; 2) What are the key biological, climatic, and oceanographic factors affecting long-term changes in Bering Sea food production and salmon growth rates?; 3) What are the similarities in production trends between salmon populations in the Bering Sea and common factors associated with their trends in survival?; and 4) Is the Bering Sea ecosystem at or near its overall limit or carrying capacity to produce salmon?

The long-term objectives of BASIS are to:

- Monitor and evaluate oceanographic and biological factors related to salmon production;
- Determine and understand the role of salmon in nektonic communities and their association to Bering Sea ecosystem status;
- Understand the causes of changes in salmon carrying capacity in the Bering Sea;
- Understand the processes that affect salmon production;
- Study the linkage between marine survival of salmon, and climate and ocean changes; and
- Predict the potential impacts of global climate change on marine salmon habitats.

Project Description

NPAFC SCIENCE PLAN 2001-2005: KEY QUESTIONS

- Seasonal-specific migration patterns of salmon and their relation to the Bering Sea ecosystem
- Key biological, climatic, and oceanographic factors affecting long-term changes in Bering Sea food production and salmon growth rates
- Similarities in production trends between salmon populations in the Bering Sea and common factors associated with their trends in survival
- Overall limit or carrying capacity of the Bering Sea ecosystem to produce salmon

BERING-ALEUTIAN SALMON INTERNATIONAL SURVEY (BASIS) 2002-2006

Monitor and evaluate environmental and biological factors related to salmon production:

- Salmon migration and distribution pattern
- Salmon feeding and growth trend
- Salmon mortality process
- Fish biomass
- Prey and predator biomass
- Oceanographic change
- Climate change



SALMON CARRYING CAPACITY

Understand the mechanisms underlying the effects of environmental variation and density-dependence on salmon carrying capacity in the Bering Sea



FORECAST

Improve the ability to forecast abundance trends in international and domestic salmon stocks



FUTURE SALMON PRODUCTIVITY

Improve understanding and forecasts of future salmon productivity in the Bering Sea



CONSERVATION OF SALMON STOCKS

Develop management plans for the sustainable conservation of salmon stocks in their ecosystems

Figure 1. Key questions in Bering Sea salmon research under NPAFC science plan, and a systematic flow indicating BASIS objectives.

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These results are expected to:

- Improve the ability to forecast abundance trends for international and domestic resource management;
- Improve understanding and forecasts of future salmon productivity; and
- Co-operate with and participate in international salmon conservation efforts.

4. Relevant Results from Prior Research

There is widespread recognition that significant changes have occurred in the Bering Sea-Aleutian Islands ecosystem over the last decade, possibly due to shifts in the Pacific Decadal Oscillation and Arctic Oscillation and influences of El Niño-Southern Oscillation (ENSO; e.g., Mantua et al. 1997; Livingston et al. 1999, 2000; Schumacher 2000; Schumacher et al. 2000). For example, the Bering Sea seasonal ice pack now exhibits earlier buildup in winter and earlier retreat in spring than in the late 1970s and 1980s (Stabeno 2001). Pollock distribution and abundance have varied with the recent fluctuations in sea ice (Ohtani and Azumaya 1995). Shifts have also been observed in crab, seabird, and marine mammal populations (e.g., Rosenkranz et al. 1998; Hunt and Byrd 1999; Springer 1998). Numbers of jelly fish have increased (Brodeur et al. 1999). Evidence indicates that the productivity of the Bering Sea has been in decline for several decades, and that this decline has accelerated in recent years. For example, Schell (1998) inferred decreases in primary (1965-1990) and secondary production (1965-1993) from a time series of carbon isotope ratios in whale baleens. Sugimoto and Tadokoro (1997) reported a decline in summertime zooplankton biomass over the southeastern Bering Sea shelf. Vast colonies of coccolithophores, a group of phytoplankton whose highly reflective plates of calcium carbonate can be easily seen by satellite imagery as turquoise blue water, began appearing on the southeastern Bering Sea shelf in the summer of 1997, and are now recurring each summer. In 2000 the coccolithophore blooms (*Emilania huxley*) began in February along the ice edge and expanded northward as the ice melted, forming a biological desert (low chlorophyll-a concentration) or “Coccolith Wall” at depths from 40 m to 80 m from February to October (T. Iida and S. Saitoh, Graduate School of Fisheries Sciences, Hokkaido University, Hakodate, Japan, unpublished data).

As described in the introduction, there is strong evidence for recent changes in salmon carrying capacity in the Bering Sea ecosystem. In 2000 Western Alaska was once again faced with extremely low chinook and chum salmon returns (McNair and Geiger 2001). In the Arctic-Yukon-Kuskokwim (AYK) region, as in some other areas of Alaska, there was a notable decrease in salmon production for many stocks. Yukon and Kuskokwim Rivers chinook salmon stocks have been classified as stocks of concern under the guidelines established in the Sustainable Salmon Fisheries Policy for the State of Alaska. Similarly, chum salmon from the Kuskokwim, Yukon (summer and fall), and Nome Areas have also been classified as stocks of concern. Kvichak sockeye salmon are another stock of concern. According to McNair and Geiger (2001), “the loss of productivity has been the subject of much interest and concern, and is probably due to poor ocean survival caused by mechanisms that are still not understood.”

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Some changes in Alaska salmon abundance have been attributed to changes in fisheries or management (e.g., Farley and Murphy 1997). Examination of historical trends in rate of fishing and productivity of Bristol Bay sockeye salmon indicated that stocks that were fished heavily during periods of low production were depleted, and that the interaction of fishing and climate-induced variation in productivity determines abundance of salmon (Eggers 1998).

A long-term decrease in body size and increase in age at return of many stocks of Asian and N. American salmon is well established (e.g., Kaeriyama 1989; Ishida et al. 1993; Bigler et al. 1996, Helle and Hoffman 1998; Watanabe 2000). Scale pattern studies indicate that this growth reduction may occur in Japanese chum salmon and Bristol Bay sockeye salmon during their second or third summers in the Bering Sea, and is correlated with high pink salmon abundance (Fisheries Agency of Japan 2001; G. Ruggerone, Natural Resource Consultants, Seattle, Washington, unpublished data). Long-term (1972-1998) Japanese high seas research vessel data shows a decreasing trend in body size of adult pink salmon and ages 0.2 - 0.4 chum salmon, and southeastward shifts in the high seas distribution of chum salmon were observed in years of high adult pink salmon abundance in the Bering Sea (Azumaya and Ishida 2000).

In the western Bering Sea in fall 2000, there was evidence of warmer than average (1981-present) sea temperatures and food competition between pink salmon juveniles and other species, particularly chum and sockeye salmon (Smorodin et al. 2001). Chum salmon in the Bering Sea switch their diets from high to low energy prey when abundance of maturing pink salmon is high (Tadoroko et al. 1996, N. Davis, University of Washington, Seattle, unpublished data). Bioenergetic modeling of observed size changes in salmon in the Bering Sea in early summer indicates that salmon are feeding at rates close to their physiological maxima, and that any reduction in daily ration could cause a significant decrease in growth over a time period as short as two months (Davis et al. 1998). Sea temperature appears to have less of an affect on growth than availability of food (Walker et al. 2000). Increases in production of hatchery fish at a time when ocean productivity is decreasing may magnify the effect of food competition on salmon growth and fertility (Volobuev 2000).

The decline in abundance of salmon in the 1990s has resulted in the lowest Canadian (British Columbia) catches in history and significant concerns for the conservation of some stocks (NPAFC 2000). There is a general recognition that the decline is related to decreased marine survival. Although these trends are largely associated with local changes in marine conditions in the waters off British Columbia, concurrent changes in the marine growth or survival of northward-migrating B.C. stocks in the Bering Sea may have an important influence of the recovery of depleted populations.

There is evidence that the freshwater and marine ecosystems of Pacific salmon have warmed in the past 25 years and expectations that this warming will continue. Atmospheric CO₂ and temperature over the Arctic have increased, and winter ice cover has decreased. Experts warn that changes in the ocean environment, biological productivity, and salmon should be monitored carefully (Nagasawa 2000). There may be some positive effects of warming on northern salmonid populations, for example, northward expansion of marine feeding and overwintering areas and formation of new freshwater spawning habitats as glaciers retreat.

Unanticipated reductions in the ocean production of Bering Sea salmon populations are affecting Asian and North American societies and economies through reduction and possible elimination of important commercial and subsistence salmon fisheries. Experts agree that the future of the

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Bering Sea salmon resource is uncertain: the lack of long-term, large-scale observation systems for salmon in the Bering Sea has inhibited scientific understanding of these declines. The only recent time series of data for salmon in the international waters of the Bering Sea is from an annual summer (late June – early July, 1991-present) gillnet survey by one Japanese research vessel, *Wakatake maru* (Fukuwaka and Ishida 2000). This sampling effort is laudable and exemplifies the type of field research that is needed, but the *Wakatake maru* data are inadequate to detect seasonal or spatial changes in distribution, growth, abundance, and origins of salmon in the whole areas of the Bering Sea.

There is direct evidence from historical high seas tagging and parasite studies that the ocean ranges of salmon from nearly all geographic regions in Asia and North America from Honshu Island, Japan, to the Sacramento River, California, extend into the Bering Sea and Aleutian Islands (French et al. 1975; Myers et al. 1996). Juvenile salmon from eastern Kamchatka, western Alaska, and the Canadian Yukon spend their first ocean summer in the Bering Sea. Older immature and maturing salmon from a broad mixture of Asian and North American stocks migrate northward each summer to feeding grounds of the Bering Sea. Some stocks, including North American chinook salmon from western Alaska, the Canadian Yukon, British Columbia, Washington, and Oregon, and Alaska chum salmon are also distributed in the Bering Sea in winter. Recently, Japanese scientists have demonstrated that the international genetic (isozyme) baseline for chum salmon can be used to accurately estimate the proportions of regional stocks in the *Wakatake maru* catches in the Bering Sea in summer (S. Urawa, National Salmon Resources Center, Sapporo, Japan, unpublished data). While the results provide only a snapshot of salmon origins at one time and in one area of the Bering Sea, the potential to expand our knowledge of stock-specific salmon distributions is limited only by the scope of our high seas field operations and the completion of international baselines for stock identification all salmon species.

5. Approach

5.1 Field Methods

The survey area consists of 105 sampling stations spaced at regular intervals across the Bering Sea: from the Aleutians north to 64°N, and from the Alaskan to Russian coasts (Fig. 2). The stations cover coastal (<50 m deep), middle shelf (50-100 m deep), outer shelf (100-200 m deep), shelf break (along the 200-m contour), and oceanic (> 200 m deep) habitats. The plan calls for four synoptic 1-month seasonal (spring, summer, fall, winter) surveys per year for 5 years. Sampling would consist of surface trawls to capture salmon of all ages, plankton tows, and sampling of ocean conditions (e.g., salinity, temperature, currents). Coordination of sampling would be through the NPAFC.

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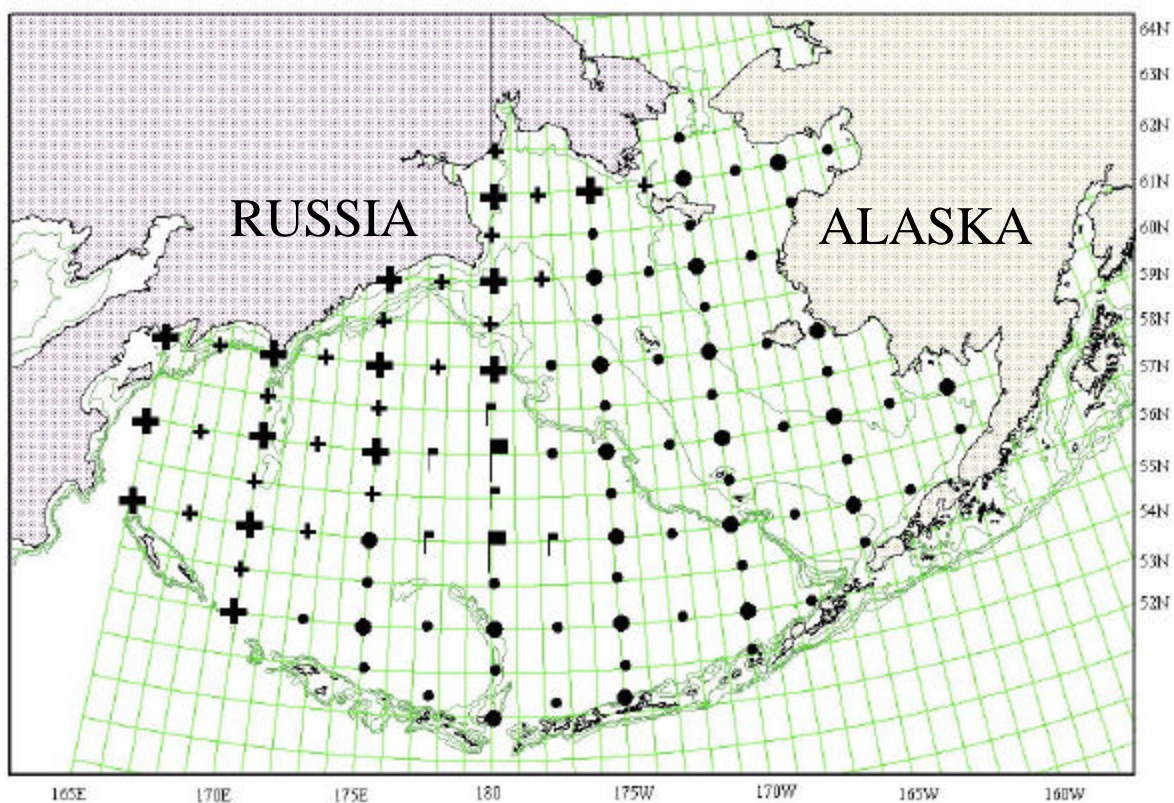


Figure 2. Sampling locations for BASIS.

- = primary stations in U.S. waters;
- = secondary stations in U.S. waters;
- + = primary stations in Russian waters;
- + = secondary stations in Russian waters;
- = primary stations in international waters;
- = secondary stations in international waters.

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5.1.1 Salmon Sampling

The plan calls for simultaneous sampling by five research vessels (total of 20 research-vessel months per year), two vessels operating primarily in the Russian Zone, two vessels operating in the U.S. Zone, and one vessel operating in international and adjacent US waters. Vessel operations of the four countries will be closely co-ordinated by joint planning and exchange of information as the survey progresses. Scientists from all NPAFC member nations will be invited to participate in the cruises of other nation's vessels, as shipboard space permits. There will be co-proprietorship by the four nations of all field survey data collected during all BASIS surveys.

The same fishing gear, a midwater rope trawl, model 400/580, made by Cantrawl Pacific Ltd. of Richmond, B.C., will be used on all vessels. The net is 198 m long, has hexagonal mesh in wings and body, and has a 1.2 cm mesh liner in the codend. The net is fished with three 60-m, 1.9-cm bridles attached at a single point to steel alloy 5-m midwater trawl doors, each weighing 463 kg, and typically fished with 200 - 250 fathoms of warp line on each door. Floats would be used on the headrope to help keep the headrope at the surface. At each station, the net would be towed for 1 hour at between 3.5 and 5 knots. When fished in this manner, the net has an approximately 13-m vertical and 44-m horizontal opening, and successfully catches all species, size, and age groups of salmon in coastal and offshore waters (e.g., Carlson et al. 1999, 2000). Replicate 1-hr net tows will be done at all stations where no salmon are caught in the first tow. Trawl tows should be executed over 24 hours with preference to night tows (if possible) over the deep-sea area. This will allow obtaining information on daily migrating mesopelagic fauna.

The cruise tracks are designed as continuous loops with north-south segments that can be truncated if necessary depending on weather, sea, and ice conditions (Fig. 3). All vessels will be equipped with Seatex Seapath 200 GPS/INU or an equivalent attitude and positioning system. Vessels operating simultaneously in the same zones will start at the same location and move in opposite directions around the survey loop. The two vessels in the Russian zone will start operations at 56°N, 165°E; the two vessels in the US Zone will start at 55°N, 165°W. The fifth vessel would sample stations along the Aleutian Islands chain between 167.5°W and 177.5°E, and north-south transects along 175°W, 177.5°W, 180°, and 177.5°E (Fig. 3). We estimate that in good weather each vessel would be able to sample two stations per day. When sea or weather conditions are poor, primary stations will receive sampling priority over secondary stations (Fig. 2). After all stations have been completed, any remaining survey time would be used to resample stations, particularly in areas where salmon were concentrated, to increase sample sizes for stock identification and to conduct coordinated experiments to evaluate the variation in fishing efficiency between the vessels.

The proposed months for the seasonal surveys are May (spring), July (summer), September (fall), and February (winter). Recent research cruises reported to the NPAFC, as well as historical information, suggest that surveys in these months would provide significant seasonal information on salmon abundance, distribution, and growth (e.g., Smorodin et al. 2000).

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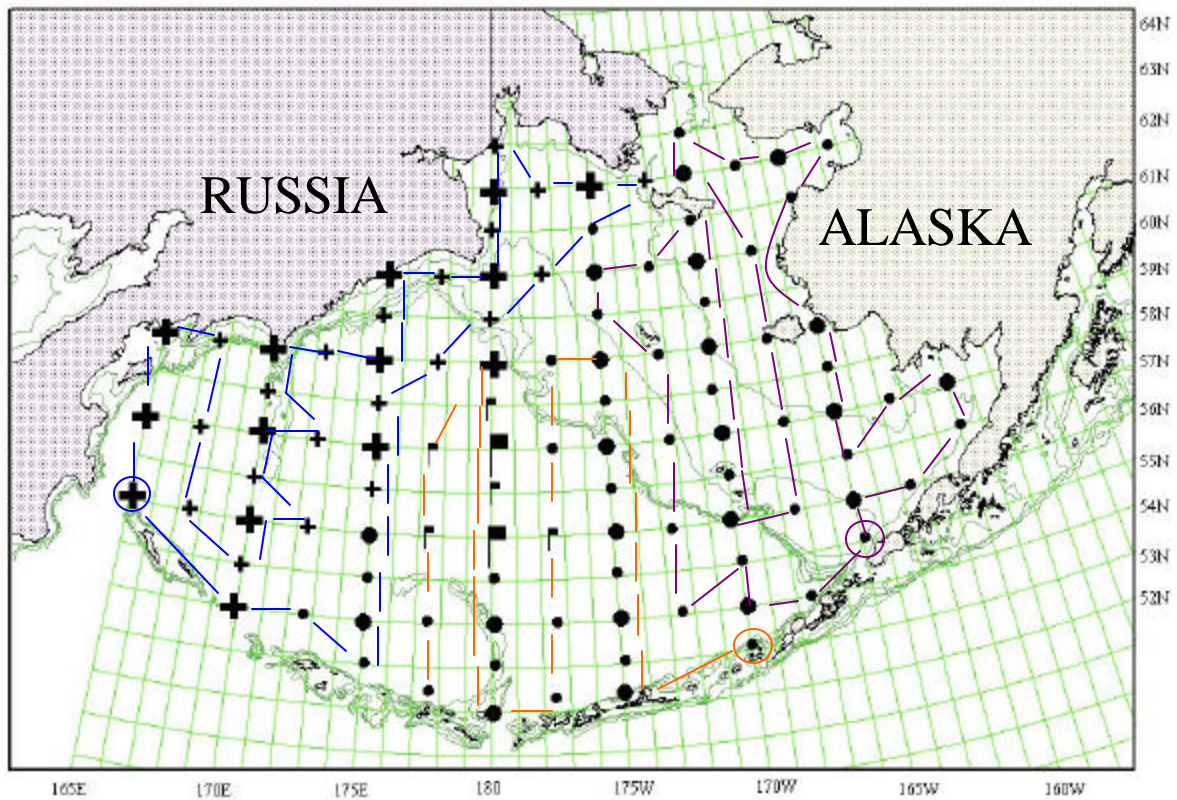


Figure 3. An example of proposed cruise tracks (arrows) for simultaneous sampling by 5 research vessels in the western (2 vessels), central (1), and eastern (2) Bering Sea. The cruise tracks are continuous bops with north-south segments that can be truncated as necessary depending on weather, sea, and ice conditions. Vessels in the eastern and western Bering Sea will move in opposite directions from the start locations (arrows show direction for 1 of the vessels). Surveys will be conducted four times per year, one survey each in spring (May), summer (July), fall (September), and winter (February).

- = primary stations in U.S. waters;
- = secondary stations in U.S. waters;
- + = primary stations in Russian waters;
- + = secondary stations in Russian waters;
- = primary stations in international waters;
- = secondary stations in international waters;
- = start locations for vessels.

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All salmon in the catches will be counted by species. The principal biological characters that will be measured include fork length (FL, mm), body weight (BW, g), sex, gonad weight, and weight of stomach contents. Japanese beam balances will be used for shipboard measurement of body and gonad weights of immature and adult salmon. Gonad weight will be used as an index of maturity. Juvenile (ocean age-.0) salmon will be frozen in the round for laboratory collection of length, weight, stomach contents, scales, otoliths, and tissues for genetic or parasite analysis. Immature and adult salmon will be sampled aboard the vessel for scales, otoliths, tissues for genetic analysis (allozyme: muscle, heart, liver, and eye; DNA: adipose fin or muscle or heart), and stomach contents (stomach content weight (g) and visually estimated % by volume of each prey category). Sample protocols for allozyme and DNA analysis established by the Alaska Department of Fish and Game will be used

(<http://www.cf.adfg.state.ak.us/geninfo/research/genetics/TECHFAC/protocol.htm#anchor183541>). All vessels will be equipped with a -80°C freezer for storage of genetic (allozyme) tissue samples. Heads will be collected from all salmon with missing adipose fins for laboratory examination for coded-wire tags.

Viable salmon not required for other studies will be tagged with external archival or disk tags and released. Experience from research tagging aboard chartered trawl vessels demonstrates that trawl-caught salmon can be successfully tagged. If two fish can be tagged at one-quarter of the total stations proposed, approximately 400 fish could be tagged. Fish would be tagged with external archival tags which record temperature, depth, and light (light data would be used to determine geolocation; Lotek tag LTD_1000) or temperature and depth (Lotek tag LTD_1110). A larger number (1,000) of smaller fish (juveniles in fall and winter) would be tagged with inexpensive small tags which record temperature only (Dallas Semiconductor iButton tag). Additional viable fish would be tagged with plastic Petersen disk tags. Tagging with archival tags would support a Census of Marine Life (CoML) program, Pacific Ocean Salmon Tracking (POST), which has been proposed by scientists from NMFS, DFO, USGS Biological Resources Division, Pacific Salmon Commission, and Hokkaido University. The CoML Steering Committee is hosted by the Consortium for Oceanographic Research and Education, an association established by the U.S. government.

All data collected aboard research vessels will be recorded on standardized catch, effort, and biological data forms. Each salmon specimen will be assigned a unique identification number. Initial computer data entry will be done aboard the vessels, but hard copies of the original data forms will be retained and made available to all participating agencies and organizations for verification of electronic records.

5.1.2 Zooplankton Sampling

A 1 m² NIO/Tucker trawl fished at the surface immediately after each tow, at about the midpoint of the tow path, will be used for zooplankton sampling for salmon prey. The mesh is 0.3 mm, and the trawl will be equipped with a digital flow meter centered in the net opening. At each station we will collect 3 replicate samples, each from a ten minute tow.

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For comparison with long-term data series, we will also collect zooplankton once a day at 2400 hours (local time) by a vertical haul (0-150 m) with a remodeled NORPAC net (GG54, 0.315 mm) and flowmeter. The remodeled NORPAC net performs well in terms of the open area ratio (6.5) and the filtration ratio (91.4%).

Zooplankton samples will be fixed immediately in 5% buffered formalin. In the laboratory, zooplankton will be sorted and identified into 12 categories (euphausiids, copepods, amphipods, pteropods, appendicularians, chaetognaths, ostracods, jellyfishes (medusae, ctenophores), salps, fishes, squids, and others identified to taxon).

5.1.3 Hydrographic Sampling

At every station a CTD cast will be made to 500-m depth at oceanic (>200 m deep) stations or within 5 m of the bottom at coastal (<50 m deep), middle shelf (50-100 m deep), outer shelf (100-200 m deep), and shelf break (along the 200-m contour) stations. All vessels will be equipped with the same hydrographic instruments: a SeaBird Electronics SBE-19 Seacat CTD equipped with a Wetstar fluorometer or equivalent to record depth, temperature, salinity, and fluorescence at 1-m intervals; and a hull-mounted RDI Workhorse Mariner Acoustic Doppler Current Profiler 300khz or equivalent to measure current velocity. Oceanographic data will be recorded following the guidelines of the NPAFC Methodology Standardization Working Group (Mackas et al. 1997), which includes information on depth, temperature, salinity, and other basic information on ocean and weather conditions (Appendix 1). Data files will be sent to the National Oceanographic Data Center (NODC) in Washington, D.C., and other national repositories.

5.1.4 Other Species

All other fish and invertebrates in the catch will be counted and weighed by species. A subsample of the non-salmonid catch will be measured (lengths, mm), weighed, and examined for stomach contents or other biological characteristics.

5.2 Laboratory Methods

Laboratory analyses will be performed by scientists at participating agencies and universities according to their areas of scientific expertise. Each component (scale analyses for age and growth, stomach content analyses, zooplankton analysis, calorimetry, genetic stock identification, scale pattern analysis, otolith marks, coded-wire tags, archival and disk tags, and parasite tags) should be regarded as a study independent but related with other components in the project.

5.2.1 Scale Analyses for Age and Growth

Ages will be determined by visual examination of scale patterns for all salmon in the catches. Scale collection and measurement procedures, similar to those described by Davis et al. (1990) and Walker et al. (1998), will be standardized and coordinated through NPAFC. Growth rates of salmon will be quantified by measurement and analysis of the scale patterns of specimens sampled for stomach contents (10-15 individuals of each species from each station). For juvenile salmon, two non-regenerated scales per fish will be collected from the preferred area, placed on gummed cards with the sculptured surface up and impressed in transparent acetate. Procedures

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for immature and adult salmon will be similar, except that scales will be mounted on gummed cards during shipboard processing. Acetate impressions of scales will be measured with a video digitizing system operated by an experienced scale reader. Scale data (incremental distances between circuli in the first ocean zone and circulus counts and total size of all subsequent annular zones) will be collected along a single radius, the longest axis, in the anterior (sculptured) field of the scale.

5.2.2 Stomach Content Analyses

Food habits of juvenile salmon will be quantified by analyses of stomach contents from frozen specimens. Ten to fifteen individuals of each species from each station will be processed. The specimens will be measured for fork and standard length and weighed. Stomachs will be excised, and the contents removed and weighed. Stomach contents will be sorted into 12 major prey categories (euphausiids, copepods, amphipods, pteropods, appendicularians, chaetognaths, ostracods, jellyfishes (medusae, ctenophores), salps, fishes, squids, and others), and the visually estimated percent volume of each prey category will be recorded. The stomach contents will be fixed in 5% formalin and preserved in alcohol for more detailed analysis and use in subsequent bioenergetic studies (e.g., identification to lowest feasible taxon, counts by prey type, blotted-dry wet weights by prey type, weight measurements of individual prey items).

5.2.3 Zooplankton Samples

Samples will be split with a Folsom splitter and consecutive fractions will be sorted and identified into 12 categories (euphausiids, copepods, amphipods, pteropods, appendicularians, chaetognaths, ostracods, jellyfishes (medusae, ctenophores), salps, fishes, squids, and others). Biomass will be estimated as the blotted wet weight of prey types in each sample.

5.2.4 Calorimetry

Wet weight, dry weight and whole body energy content will be measured for approximately 10-15 frozen salmon of each species and major age-maturity group for salmon caught in coastal, middle shelf, outer shelf, shelf break, and oceanic habitats in the eastern and western Bering Sea in each season and year. The specimens will be freeze-dried, or placed in a convection drying oven at 60°C until they reach constant weight, and then homogenized in a mill and pressed into pellets of about 0.15 g. Pellets will be burned in a Parr semi-micro bomb calorimeter to determine whole body energy content. Mean energy content of salmon will be calculated as cal/g dry weight and Joules/g wet weight. Bomb calorimetry will also be used to measure prey energy content when literature values are not available (see Davis et al. 1998 for methods).

5.2.5 Stock Identification Analyses

Many stock identification techniques are still in the developmental stage, therefore any technique that holds promise of distinguishing populations of Asian and North American salmon may be used. The methods will include but are not limited to genetic stock identification (allozyme electrophoresis, mitochondrial DNA, and microsatellite DNA), scale pattern analysis, otolith marks, coded-wire tags, archival and disk tags, and parasite tags. Measurements, techniques of measurements, sampling protocols, and analytical procedures will be closely coordinated by the NPAFC *Ad Hoc* Working Group on Stock Identification.

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5.2.5.1 Genetic Stock Identification

Genetic stock identification (allozyme, mitochondrial DNA, and nuclear DNA markers) will be used to estimate the proportions of regional population assemblages of Asian and North American salmon in BASIS catches. The most current comprehensive allozyme and DNA databases for all species will be used (NPAFC 2001). Data sets from baseline populations will be enlarged as necessary to improve coverage of populations contributing to the Bering Sea. The Parties will standardize the baseline and survey data collected under BASIS, and the resulting data sets will be coordinated and distributed by the Ad hoc Working Group on Stock Identification.

Conditional maximum likelihood analysis (CMLE) will be the primary means of estimating proportions of stock groups in BASIS mixtures. These likelihood estimates are conditional on the assumption that the distributions of identifying characteristics are known without error for each population potentially contributing to the mixture. Computer simulations with samples from known mixtures of baseline populations will be used to investigate the effects of mixture sample sizes and population assemblages on the accuracy of maximum likelihood estimates. Unconditional confidence interval estimates will be approximated by bootstrap resampling from both the mixture sample and baseline distributions. Additional statistical techniques will be evaluated to investigate the behavior of hypervariable loci in mixture analyses and to identify the best combination of loci for a particular application.

5.2.5.2 Scale Pattern Analysis

Scale pattern analysis (SPA) is a well-established technique that has been used to estimate origins of salmon stock mixtures in high seas catches since the 1950s. Where SPA is used as the primary technique for quantitative estimates of stock composition, baseline data will be re-established annually to account for annual variations in scale growth. Our approach will include the measurement of scales from major stocks of Asian and North American salmon (reference samples), development of multivariate scale pattern models (baselines) from the reference samples, and estimation of stock composition of high seas mixtures by statistical techniques. Arrangements for exchanges of scale samples and associated data among nations will be made through NPAFC. Composite regional baselines (stocks with similar scale growth patterns in the first ocean zone) will be formed from fish of the same freshwater age and brood year as the fish in the BASIS catches.

Principal components of scale pattern variables will be used in conditional maximum-likelihood mixture models to estimate proportions of regional salmon stocks in the survey area (Millar 1987, 1988, 1990). Computer simulations will be used to test the effects of mixture sample sizes and population assemblages on the accuracy of maximum likelihood estimates. Unconditional confidence interval estimates will be obtained by bootstrap resampling from both the mixture sample and baseline distributions.

5.2.5.3 Otolith Marks

Marks induced on the otoliths (ear bones) of salmon embryos are widely used in Asia and North America to mass mark hatchery-reared salmon. In 2000, releases of otolith marked pink salmon

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were the highest (631 million), followed by chum (328 million), chinook (18 million), sockeye (32 million), and coho (0.1 million) salmon (Urawa et al. 2001). Otolith mark recovery data from BASIS catches will enable us to develop a valuable time series of stock-specific observations on the distribution, migration routes, feeding success, condition, and growth of otolith-mark release groups. The left and right sagittal otoliths from all pink and chum salmon will be removed. The left sagittal otoliths will be mounted sulcus-side up, using thermal resin, on petrographic slides, and then ground to expose primordia. If left sagittal otoliths are not available or are overground, then right sagittal otoliths will be used. Otolith microstructure will be examined under a compound microscope, and the microstructure patterns will be compared to mark patterns from Asian and North American hatchery voucher specimens. All otoliths will be read independently by a second reader to minimize reader error and provide confidence in readings (Hagen et al. 1995).

The NPAFC Working Group on Salmon Marking will coordinate the use of otolith marks to minimize duplication between countries, and will establish a common database of mark releases and recoveries, and web access to the database.

5.2.5.4 Coded-wire Tags

Coded-wire tags (CWTs), implanted into the nasal cartilage of juvenile salmon, are widely used for stock identification by fisheries agencies on the West Coast of North America. Annual tagging levels of chinook salmon are the highest (about 35 million), followed by coho (7 million), chum (2 million), pink (1 million), and sockeye (1 million) salmon (unpublished data, Pacific States Marine Fisheries Commission, Gladstone, Oregon). Adipose fin clips are used as an external mark to indicate that a fish is coded-wire tagged. Snouts will be collected from all salmonids lacking the adipose fin. The NMFS, Auke Bay Laboratory, will receive snouts and decode any CWTs that are found. CWT release data will be obtained from the Regional Mark Processing Center, Pacific States Marine Fisheries Commission (PSMFC), and BASIS CWT recovery data will be incorporated into the PSMFC coastwide, on-line CWT recovery data set (Regional Mark Information System (RMIS), http://www.rmis.org/cwt/cwt_qbe.html). Release and recovery data will be reported annually to the NPAFC.

5.2.5.5 Archival and Disk Tags

Information from tag returns will be critical direct evidence of distribution of stocks in the Bering Sea. This evidence can be used to verify results of indirect methods of stock identification, such as genetic stock identification and SPA. Data from geolocation archival tags will yield important information on migration routes of stocks. Data from temperature-depth and iButton tags will provide necessary actual daily temperatures required by bioenergetics models (see 5.3.1 below).

5.2.5.6 Parasite Tags

Naturally occurring parasite tags may be used in combination with other techniques for stock identification of salmon in BASIS catches. Where parasites are used as the primary techniques for quantitative estimates of stock composition, baseline data will be re-established annually to account for annual variations in parasite prevalence (% of stock with the parasite) and intensity

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(numbers of parasites in each host) among the stocks to be distinguished (Margolis 1998). If parasite tags are deemed of value, collection will be made at sea and in the laboratory.

5.3 BASIS Modeling

The participating agencies and universities will use BASIS data to develop spatially-explicit models incorporating oceanographic data and salmon migration, growth, and mortality processes to advance our understanding of the causes of changes in productivity of salmon populations.

5.3.1 Bioenergetic Modeling

Bioenergetic modeling will be used to evaluate the seasonal productivity and salmon carrying capacity (defined by salmon growth potential) in different habitats (coastal, middle shelf, outer shelf, shelf break, and oceanic) in the eastern and western Bering Sea and to estimate prey consumption for all species of salmon. Growth potential will be estimated by modeling consumption with an encounter rate model (Gerritsen and Strickler 1977) and using a bioenergetics model (Hanson et al. 1997) to calculate daily weight-specific growth (growth potential) with inputs of: 1) prey consumption rates based on predator/prey encounter rates, 2) the temporal pattern in diet composition over the period of interest; 3) the average daily temperatures that the salmon experienced over the period of interest, and 4) the energy density of salmon and their prey.

5.3.2 Dynamic Models of Salmon Migration and Growth

BASIS data will be used in a NerkaSim (Rand et al. 1997) shell customized for the Bering Sea. NerkaSim can be used to (1) archive and visualize biophysical oceanographic data; (2) execute a spatially explicit, individual-based Pacific salmon model that can include migration, growth, and mortality processes; and (3) produce graphical images of simulated migration trajectories and bioenergetic variables in both space and time (e.g., see model for migrations of Fraser River sockeye salmon in the eastern North Pacific Ocean, <http://www.eos.ubc.ca/salmon/nerkasim/>). Models will be developed for different species, stocks, age, and maturity groups of salmon across the Bering Sea to address key questions in the 2001-2001 NPAFC Science Plan (see section 3) and to advance our understanding of the mechanisms underlying the effects of environmental variation and density-dependence on salmon carrying capacity.

5.4 Final Synthesis and Review

The scientific results of the entire 5-year cooperative research effort will be synthesized, reviewed, and published in the NPAFC Bulletin series as a joint comprehensive report on salmon in the Bering Sea.

5.5 Relationship Between BASIS and Current Bering Sea Salmon Research

BASIS expands current research conducted by the US and Russia on juvenile salmon in the coastal zones to include other life history stages in offshore zones. BASIS also increases temporal and spatial coverage of the Japanese research being conducted along the 180° line in the Bering Sea by the *Wakatake maru* (gillnetter).

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5.6 Project Relevance and Benefits

- BASIS provides the first ever synoptic seasonal information on distribution, abundance, and stock origins of all species, age, and maturity groups of salmon in the Bering Sea;
- BASIS directly addresses the key elements of the 2001-2005 NPAFC Science Plan;
- BASIS complements long-term climate, ocean, and ecosystem research and monitoring activities by other international organizations such as the North Pacific Marine Science Organization (PICES) and Global Ocean Ecosystem Dynamics (GLOBEC).

5.7 Project Management

The NPAFC BASIS Working Group (BWG), composed of members from each of the four Parties, will coordinate individual national plans, draft an annual implementation plan for joint BASIS research, and draft an annual report to summarize BASIS results (Fig. 4).

Annual cruise plans, cruise reports, data reports, and documents showing preliminary results of laboratory analyses and computer modeling will be submitted to NPAFC for review and evaluation. We think it is important for individual researchers to publish the results of each aspect of the research (e.g., salmon, zooplankton, and oceanographic data). Principal investigators, project participants, and modelers will cooperate in constructing a dynamic model of salmon in the Bering Sea. BWG will prepare a final synthesis and review of all aspects of the research for publication in the NPAFC Bulletin series.

5.7.1 National Research Plans

Each country will propose an annual national research plan for BASIS. Submitted plans will be coordinated and compiled as the joint project of four nations by the BASIS Working Group (Fig. 4).

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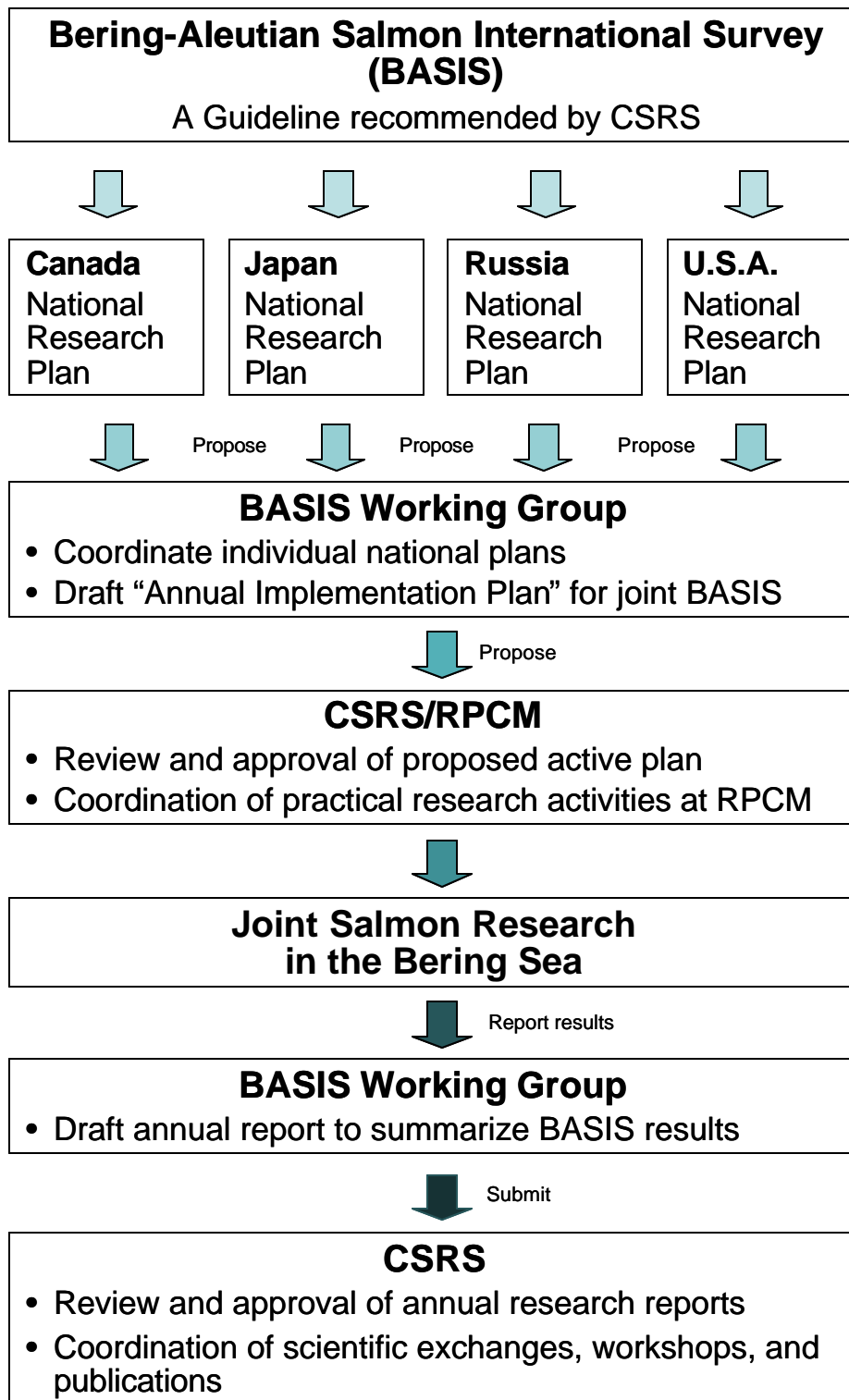


Figure 4. A flow chart indicating the planning and coordination of BASIS.

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5.7.2 NPAFC Research Planning and Coordination

The CSRS research planning and coordinating activities will include: 1) annual review and coordination of the collection and exchange of scientific data and collection of specimens; 2) coordination and assessment of stock identification research; 3) coordination of scientific exchanges, seminars, workshops, field research, and data analyses; 4) review of proposed research plan; and 5) review and approval of reports submitted for publication and recommendations regarding other reports to be published (Fig. 4). In addition, the CSRS will make recommendations on cooperation, as appropriate, with PICES and other relevant organizations involved in Bering Sea research.

Scientists will meet annually at NPAFC Research Planning and Coordinating Meetings in March to plan and coordinate research activities, and at NPAFC Annual Meetings in October to review results and prepare an annual report to the Commission. A symposium on Bering Sea salmon would be held in three years (halfway through the research program) with the objective of summarizing work done to date and laying out options for BASIS models (see section 5.3).

5.8 BASIS Data Policy and Principles

The purpose of BASIS data policy is to facilitate full and open access to the highest quality of data. BASIS principal investigators and project participants must support this data policy.

I. No-cost, open, voluntary and ethical exchange of data or other BASIS-related information.

Publication of results immediately and directly from field and laboratory data is the privilege and responsibility of the investigators who collect the data. Any scientist making substantial use of a data set should anticipate that the data collectors would be co-authors of published results. Originating investigators may not unreasonably impede use or publication of archived data, models, or model application. After a two (2)-year proprietary period has elapsed, the data will be submitted to a national data center for permanent archival, and the data will be in the public domain.

II. Methods and equipment used to take measurements and collect samples must be of sufficient accuracy and precision to yield data with quality adequate to meet the objectives of the BASIS field projects, associated modeling efforts, and larger-scale synthesis.

Final responsibility for selection of methods, equipment, and calibration procedures is assigned to the investigators making measurements. However, the procedures that will be used to collect and process samples and data will be considered in the review process.

III. A data archive system will be established for each project component within six (6) months of the project start date for temporary repository of the data prior to their submittal to a permanent archive.

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The data archive system must facilitate the exchange of data and insure the long-term existence of the data set. Each investigator will be responsible for quality control of his or her data. The data will include the actual measurements and supporting descriptive information sufficient to permit its effective use by researchers not familiar with the original project or the particular instrument making the measurements (e.g., location, time, units, accuracy, precision, method of measurements or sampling, method and rate of sensor calibration and calibration data, investigator, reference to publications describing the data set, and data processing methods). Raw genotype scores for individual fish for both mixture and baseline samples will be archived for genetic data.

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Appendix 1: Guideline for Collecting Oceanographic Observations

Tasks	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Field Collections/Year 1											
Lab and Data Analyses/Year 1											
Report Prep/Year 1											
Research Plan Meeting/Year1											
Field Collections/Year 2											
Lab and Data Analyses/Year 2											
Report Prep/Year 2											
Research Plan Meeting/Year 2											
Annual Review Meeting/Year 2											
Field Collections/Year 3											
Lab and Data Analyses/Year 3											
Report Prep/Year 3											
Research Plan Meeting/Year 3											
Annual Review Meeting/ Symposium Year 3											
Field Collections/Year 4											
Lab and Data Analyses/Year 4											
Report Prep/Year 4											
Research Plan Meeting/Year 4											
Annual Review Meeting/Year 4											
Field Collections/Year 5											
Lab and Data Analyses/Year 5											
Report Prep/Year 5											
Research Plan Meeting/Year 5											
Annual Review Meeting/Year 5											
Final Synthesis and Publication of Joint Comp. Report /Year 6											

I. Records of geography, weather, and others

- (1) Depth of sea bottom (m)
- (2) Color of sea (Forel's scale of color)
- (3) Transparency (m)
- (4) Wave (direction and degree)
- (5) Swell (direction and degree)
- (6) Air temperature

References Cited

II. Weather Records of geography, weather, and others

- (1) Depth of sea bottom (m)
- (2) Color of sea (Forel's scale of color)
- (3) Transparency (m)
- (4) Wave (direction and degree)
- (5) Swell (direction and degree)
- (6) Air temperature
- (7) Weather
- (8) Cloud (type and amount)
- (9) Wind (direction and degree)
- (10) Atmospheric pressure (mb)

III. Oceanographic observation

- (1) Instruments for oceanographic observation
- (2) Temperature and salinity at fixed layers
- (3) Fixed layers: 0m/10/20/30/50/75/100/125/150/175/200/250/300/400/500/1000